Small Business Innovation Research/Small Business Tech Transfer

High Performance Multiphase Combustion Tool Using Level Set-Based Primary Atomization Coupled with Flamelet Models, Phase II

Completed Technology Project (2014 - 2016)

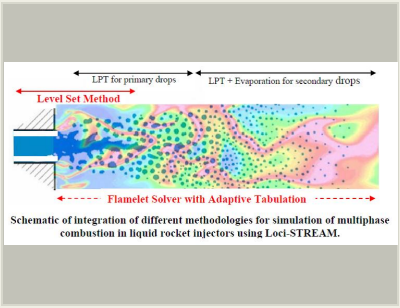
Project Introduction

The innovative methodologies proposed in this STTR Phase 2 project will enhance Loci-STREAM which is a high performance, high fidelity simulation tool already being used at NASA/MSFC for a variety of CFD applications. This project will address critical needs in order to enable fast and accurate simulations of liquid space propulsion systems of relevance to NASA's Space Launch System (SLS) program (LOX/RP-1 engines such as F-1 or potential replacement of RD-180, and LOX/LH2 engines such as RS-25, RS-25D/E, RL10, J-2X). The key methodologies which will be integrated into a production version of the Loci-STREAM code are the following: (a) Primary atomization modeling using Level Set methodology to model the liquid (core) jet, (b) Lagrangian particle tracking (LPT) for the droplets resulting from primary atomization, (c) Evaporation models for the droplets, (d) Flamelet models for turbulent combustion, (e) Adaptive tabulation for flamelet models, and (f) Hybrid RANS-LES (HRLES) methodology. Integration of the above methodologies into Loci-STREAM will result in a state-of-the-art multiphase combustion modeling tool which will enable fast and accurate design and analysis of liquid rocket engine flow environments, combustion stability analysis, etc. which constitute critical components of space propulsion engines that are part of NASA's SLS.

Anticipated Benefits

The outcome of the proposed Phase 2 research and development activities will be an advanced version of a CFD-based multiphase combustion code called Loci-STREAM for spray combustion simulations in liquid propulsion engines of relevance to NASA. Loci-STREAM code is already being used at NASA/MSFC and the capabilities added into the code as a results of this project will make Loci-STEAM a powerful design and analysis tool for propulsion devices including full rocket engine simulations, injector design, etc. This tool will have a direct impact on development of propulsion systems relevant to the SLS by enabling design improvements of injectors involving liquid propellants such as LOX, LH2, LCH4, RP1, etc. Specific applications at NASA of this capability will include: (a) Fast and accurate simulation of turbulent combustion in existing or new/modified liquid space propulsion engines (LOX/RP-1 engines such as F-1 or potential replacement of RD-180, and LOX/LH2 engines such as RS-25, RS-25D/E, RL10, J-2X) (b) Fast and accurate 3D unsteady simulations of multi-element injectors coupled with fuel and oxidizer feed lines and manifolds which will yield high-fidelity information for combustion instability models, (c) Prediction of stability and stability margins, (d) Design of acoustic cavities for combustion stability, etc.

The enhanced version of the computational tool Loci-STREAM resulting from this project will have wide-ranging commercial applications. The Hybrid



High Performance Multiphase Combustion Tool Using Level Set-Based Primary Atomization Coupled with Flamelet Models, Phase II Briefing Chart Image

Table of Contents

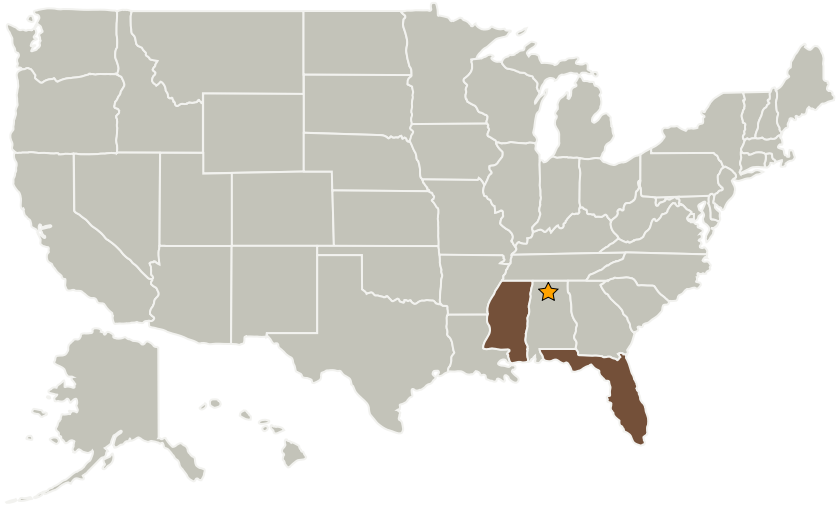
Project Introduction	1
Anticipated Benefits	1
Primary U.S. Work Locations and Key Partners	2
Project Transitions	2
Organizational Responsibility	2
Project Management	2
Technology Maturity (TRL)	2
Images	3
Technology Areas	3

High Performance Multiphase Combustion Tool Using Level Set-Based Primary Atomization Coupled with Flamelet Models, Phase II

Completed Technology Project (2014 - 2016)

RANS-LES (HRLES) methodology can be used for a wide variety of engineering applications involving unsteady turbulent flows. The high-fidelity turbulent combustion simulation capability will lead to improved analysis of unsteady turbulent reacting flow fields in gas turbine engines, diesel engines, etc. leading to design improvements. The real-fluids methodology can be used in a large number of industrial flow situations involving both chemically inert and reacting flows. With additions of multi-phase combustion modeling capability, the applicability of this tool can be further broadened.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Marshall Space Flight Center(MSFC)	Lead Organization	NASA Center	Huntsville, Alabama

Primary U.S. Work Locations	
Florida	Mississippi

Project Transitions

September 2014: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Marshall Space Flight Center (MSFC)

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

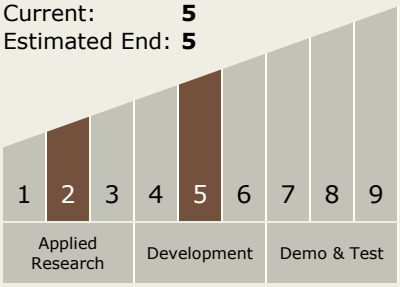
Carlos Torrez

Principal Investigator:

Siddharth S Thakur

Technology Maturity (TRL)

Start: **2**
Current: **5**
Estimated End: **5**

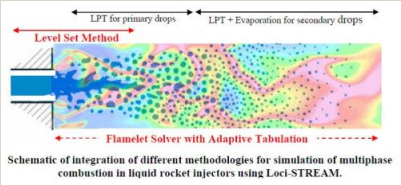


High Performance Multiphase Combustion Tool Using Level Set-Based Primary Atomization Coupled with Flamelet Models, Phase II

Completed Technology Project (2014 - 2016)

September 2016: Closed out

Images



Schematic of integration of different methodologies for simulation of multiphase combustion in liquid rocket injectors using Loci-STREAM.

Briefing Chart Image
High Performance Multiphase Combustion Tool Using Level Set-Based Primary Atomization Coupled with Flamelet Models, Phase II Briefing Chart Image
(https://techport.nasa.gov/image/30445)

Technology Areas

Primary:

- TX14 Thermal Management Systems
  - TX14.1 Cryogenic Systems
    - TX14.1.5 Cryogenic Analysis, Safety & Properties